BELLCOMM, INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D.C. 20024

B70 10063

SUBJECT: State of the Art of Electrocardiogram Computerized Display
Case 103-7

DATE: October 28, 1970

FROM: M. J. Reynolds

ABSTRACT

This memorandum reviews the state of the art of electrocardiography, with emphasis on both wireless systems and computer data reductions. Computerized electrocardiograms, in combination with wireless telemetry, have been used in the past decade for systematic heart monitoring. The computer program solicits the physician's intervention only in abnormal situations. Telemetry permits remote diagnosis or reasonably free motion for the patient. Such techniques appear to be in an advanced state of development and could be potentially applied in the Manned Space Program.

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MEMORANDUM FOR FILE

Introduction

More than seventy years ago, Professor William Einthoven developed the electrocardiograph. In the past decade computerized electrocardiograms have been implemented in the medical field providing the physician with an automated system to monitor cardiac activity, and alert him to render service only when a heart malfunction is detected. These innovations in the medical field could reasonably be added to the manned space flight program. With the computerization of electrocardiographs, astronaut cardiac activity can be automatically monitored until a change in cardiac activity triggers the physician's attention.

At present, many companies are researching and marketing electronic heart reading mechanisms for use in hospitals and medical centers. This memorandum reviews the state of the art of electrocardiography, with emphasis on both wireless systems and computer data reduction.

Technological Advances in Electrocardiographology

In 1968, the Schaefers Ambulance Service of Los Angeles adopted the medical instrument techniques developed by NASA for its test pilots. The ambulance service attaches bare wires to the patient's chest thereby forming electrodes for monitoring the electrical activity of the heart. The information from these electrodes is relayed by short-wave radio and telephone lines to a Medical Center (in this case at UCLA). At the Medical Center, the information is utilized to derive a standard electrocardiograph record providing a visual display of the patient's heart activity for the waiting doctors.

Also in Los Angeles, the Myocardial Infarction Rescue Unit (MIRU) is operational. This electronic equipment is made by DALLONS INSTRUMENTS, a division of International Rectifier Corporation. MIRU consists of: a cardioscope to

display the patient's heart activity; a heart-rate meter with alarm settings to trigger other equipment when an extreme is reached; and an elapsed-time meter to measure the time between heart beats. The information from these instruments is transmitted to the hospital where diagnoses take place and remedial instructions are relayed. The Myocardial Infarction program enables the researcher to command immediate display of derived parameters, correlograms, histograms, tables, graphs, etc., and vary these functions according to schemes of his choice.

Dr. Pipberger, head of the Veterans Administration Hospital Research Support Center, Mt. Alto, and co-workers have developed screening tests for automatic analyses of electrocardiograms. The heart pulse of the patient is converted to digital information which is fed into the computing devices for display, analysis, and recognition of:

1. The duration of the P waves - is measured to detect abnormalities in the pacemaker, which is a group of tissues with certain natural rhythm located near the atrium of the heart.

2. The PR interval, measuring the time between auricle and ventricle contraction. This is the conduction time from pace maker to the ventricle.

3. The QRS duration measuring the time needed for the ventricle to contract.

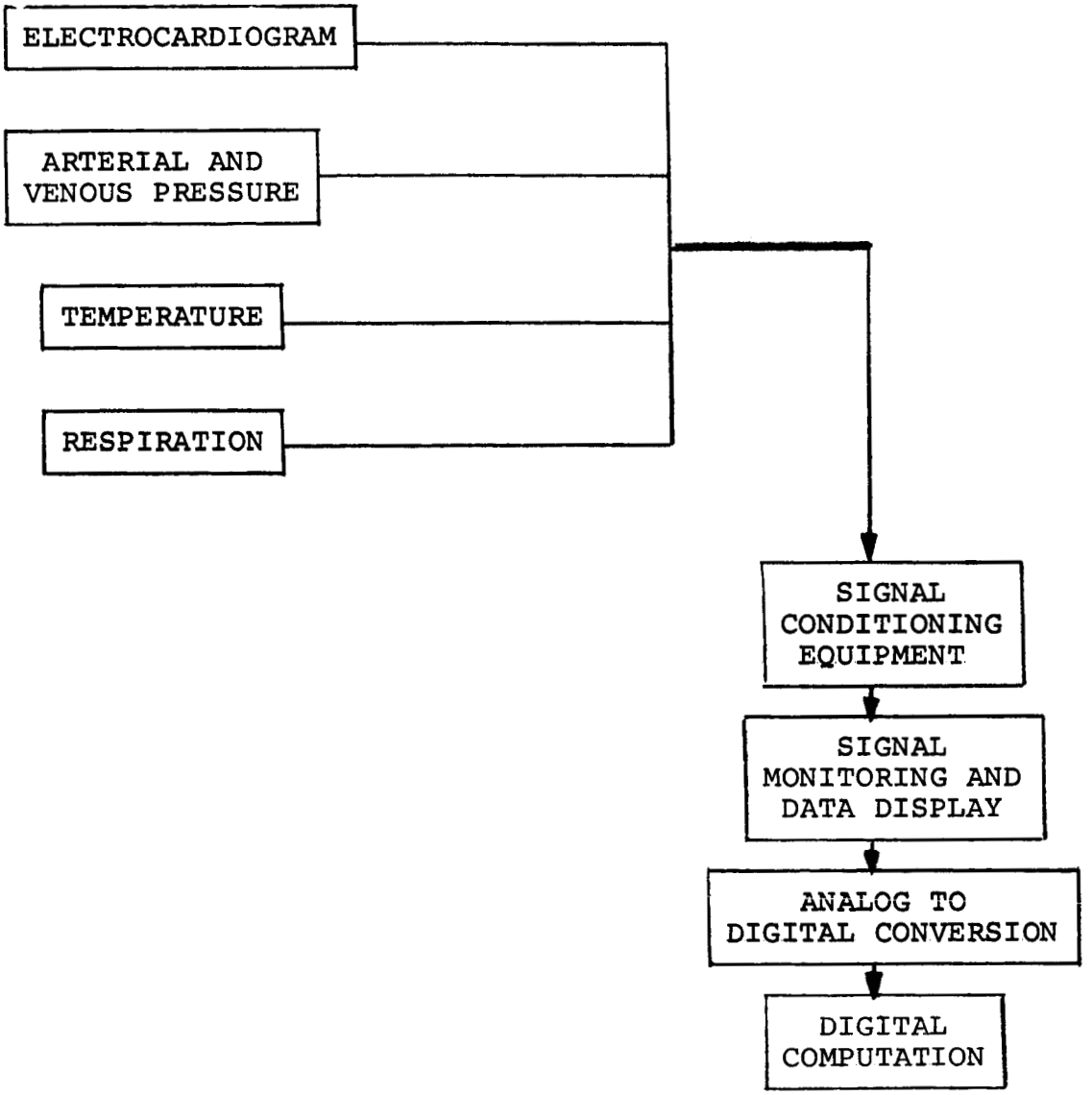
4. The QT interval measuring the time from ventricle contraction to repolarization.

Furthermore, with this information stored, large-scale statistical studies, epidemiological investigations and mass screening programs can be facilitated.

Cesar A. Caceres of the U. S. Public Health Service, Head of the Heart Disease Control Program also pioneered in this field as did Dr. Pipberger. Dr. Caceres digitized the signal complex of the P-QRS-T at a frequency of 625 cycles per second. The following 18 parameters are measured, analyzed and may be reported on an on-line (real time) basis: amplitude of P, Q, R, S, T, U, ST onset, ST mid, ST end, duration of P, Q, R, S, T, S-T, PQ, QT, P-R.

The Public Health Service developed a computer program to measure such wave forms of the ECG. Through a comparison of these amplitudes and durations with standard

tables, abnormalities can be pinpointed and corrective measures taken immediately.



The computer displays data at a distant location thereby facilitating remote monitoring.

Hewlett-Packard manufactures the Model 7893A Monitorscope which provides a large screen with various sweep speeds. Their Model 7825A Trend Recorder provides a 24-hour record of one to four different variables. Thus, there exists wide flexibility in chart format. To insure reliable, unattended recording, this unit provides permanent electric writing recordings. When the Trend Recorder is combined with an arrhythmia monitor measuring width of the overall pulse (QRS), a system providing the necessary alarms and a permanent record of the patient's abnormal heart beats is realized.

Research in electrocardiograph readings is also pursued in Europe. The T. E. M. Instruments Ltd. of Sussex, England, developed a device for automatically recording heart-rate activity over a given period of each day. This tiny instrument is known as SAMI/HR (Socially Acceptable Monitoring Instruments/Heart Rate) and obtains its signal from two adhesive chest electrodes. Electronics World summarizes the process:

> "The electrical heart beat signal is amplified and filtered by the circuits in the SAMI/HR and converted to a constant-current charge pulse. This pulse is recorded in an electrochemical integrator or E-cell (manufactured by the Bissett-Berman Corporation of Los Angeles). The E-cell recordings may later be recoded by an E-cell replay machine to determine the number of heart beats in a given period of time."

At the present, research on SAMI/HR is underway to estimate psychological as well as physical stress.

Marquette Electronics, Inc., of Montreal has developed and tested another ECG-Computer interface. This unit records electrical impulses, completing a measurement in ten seconds. It automatically records tracings from twelve leads in the body in sets of threes on a single sheet of paper as contrasted to single tracings on a continuous roll of paper. This unit is already in use in ten U. S. and Canadian hospitals, and since it can be adapted for transmission over telephone wires, the data can potentially be fed into a central processing unit.

The apparatus worn by the monitored patient was designed by Lockheed Aircraft among others. William H. Tygart of Lockheed Aircraft in Atlanta was granted patents for a transmitter and receiver while Ernest Fuller obtained the vest patent. When the vest is worn the electrodes are in place on the torso, arms and legs. Wires from electrodes run to the transmitter on which a telephone receiver can be placed. Both transmitter and receiver are portable. The receiver then converts the audible

signals for the electrocardiograph mechanism. Since no actual wire connection is necessary, the patient can move freely while the doctor can read the ECG and give advice from a remote site.

Another such data transmitter was developed by Baganoff Associates, Inc. This telecommunications device permits transmission of analog signals such as ECG, EEG, and other psychophysiological data by conventional telephone. The device accommodates from one to eighty analog signals simultaneously. The unit is acoustically coupled with the telephone.

The United States Public Health Service's Medical Systems Development Laboratory (MSDL), presently guided by Dr. Donald R. Barnes, designed specifications used to produce an analog system including a submodule that transmits data -- again by standard telephone. However, this digital acquisition system incorporates analog-to-digital conversion at the time of recording and greatly reduces processing time. Thus, large quantities of ECG readings were transmitted over analog data transmission lines (via the telephone) and analyzed by a digital computer. The computer sends back digital measurements and an English language interpretation.

If automated monitoring is desired, a device such as the Electrocardio Analyzer can be utilized. Developed by Thiokol Chemical's Humetrics Division, this miniaturized computer compares the subjects' ECG pattern with set, preprogrammed standards. Upon detection of abnormal electrical activity, a warning signal flashes. Presently, this compact device is implemented by the Los Angeles White Memorial Medical Center.

Analytical Advances

A doctor is not always available when an ECG abnormality is detected. A collaborative study with Dr. George D. Beiser of the Heart Institute has yielded a computerized analytic/diagnostic program. This program scrutinizes the waveform of the ECG in question which is supplied to it from a remote terminal. If a quick scan of the heart action is desired, only 200 waveforms/second (each composed of twelve bits of information) need be transmitted. However, up to 800/second heart pulse waves can be sampled at one time to permit an in-depth study. Following processing, a tentative diagnosis is sent back to the transmitting station providing rapid, standardized interpretation of the ECG. Furthermore, research is underway to correlate symptoms of diseases with known remedies in one data bank area to insure the most accurate diagnosis without the assistance of a physician.

Analysis of large amounts of electrocardiographic data can also prove burdensome due to the twenty-four hour acceptance of cardiac information. However, research is underway at the Department of Medicine and Biomathematics at the Duke University Medical Center, North Carolina, to reduce the data yet increase the efficiency of analyses. Howard K. Thompson and Max A. Woodbury have devised a computer program for representation of clinical data in multidimensional space. At present, it handles the data from the Myocardial Infarction Rescue Unit. If, for example, fifty patients were under observation, each person would be represented as a point in the n-dimensional space projected on a plane; where n equals the number of variables observed (such as: P-R intervals, abnormal rhythms, body temperature). Thereupon a quick glance at the graph could yield awareness of abnormalities and expedite diagnosis. Similarly, the mathematical concepts and programming machinery could be utilized to represent a single person over a period of time. Here, each dimension in the multidimensional space would refer to an observed variable.

Engineering Considerations

The engineering considerations for a sophisticated cardio-monitoring system are important to insure efficiency. First, since instruments cannot usually be located adjacent to the computer, it is essential to thoroughly evaluate analog and digital techniques. A second consideration is based on the design and implementation of remote operator consoles. These consoles must verify computer status, transmit identification information, enter data, and display immediate or final results. Lastly, a real-time monitor is essential if analysis programs and computations are to be permitted during continuous data acquisition. Generally, this monitor must be adapted to the specific task.

Summarizing Comment

The state of the art of telemetered, computerized electrocardiography is advanced. It is evident that such techniques are potentially useful not only to monitor a patient's heart activities in order to diagnose cardiac malfunction quickly, but also to observe the heart responses of men in potentially dangerous, awkward, or exotic environments. Computerized electrocardiography could readily be incorporated into the Manned Space Flight Program as an operational heart monitoring system.

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Attachment
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